ABSTRACT

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Title of Doctoral Thesis: The methodology of measurement of biomechanical properties of biological materials

As a part of this dissertation thesis a methodology of measurement of mechanical properties of viscoelastic materials was developed. The methodology was then verified and applied in measurement of shoulder-blades of pheasants and in measurement of the trabecular section of human *caput femoris* in bending and twisting stress, viscoelastic parameters of these materials were also calculated. Results, in the case of human bones, were compared with measurement of body mass density and content of vitamin D.

Mechanical behaviour of many biological materials corresponds to the behaviour of so-called viscoelastic body. These materials cannot be categorized simply as solids or liquids. The mechanical behaviour of this type of materials has partially elastic and partially viscose character. Skin, cell walls, bones, numerous structures of internal organs and many other materials belong to this category.

In spite of the fact that in physiological conditions biological materials are loaded dynamically, in specialized literature references to measurement of dynamic characteristics (e.g. frequency, impulse or transient) are rare and only marginal. The same holds for apparatuses for dynamic measurements of biological materials. From a theoretical point of view, integrated theory of quantitative description of dynamics of deformation in biological systems virtually does not exist. However detail knowledge of mechanical behaviour of biological materials is often crucial in medical and biological research. Similarly, the study of mechanical properties of materials, applied in pharmaceutical technology, is of paramount importance for pharmacy.

Progress in this field depends on availability of apparatuses for measurement of dynamic characteristics of biological material and on methodology of rheological models identification and their parameter estimation. Optimally, analysis should result in solution of so called “inverse problem”. Applicable methodology of measurement and data processing should provide information on dynamic stiffness or complex mechanical impedance, optimally also on complex modulus of elasticity. Convenient apparatuses are not available

for wider use in biological laboratories, nevertheless, there is a great potential for application of such apparatuses in many clinical and diagnostic branches.

Therefore, the aim of this dissertation thesis was to developed and tests the methodology of measurement, and to describe how the dynamics of deformation responses depends on the dynamics of loading of bone samples. Based on this experiment, we wanted to derive differential equations describing this relationship, models and adequate parameters. As test material, the shoulder-blades of pheasants and the trabecular section of human *caput femoris* has been chosen. The behaviour of samples of bones corresponds to Voigt's model. The shoulder-blades of birds served as trial material, in spite of the fact that bones of birds are, in light of mechanics, inhomogeneous material. The following characteristics of bones of birds were measured: Young's modulus in bending stress, shear stress modulus, viscouse coefficient in twisting stress. Within the frame of the thesis shear stress modulus and viscous coefficient were measured in our laboratories. This material was used to verify reproducibility and sensitivity of our methodology. The samples of the shoulder-blades of pheasants showed that the methodology is functional. It was consequently applied for the measurement of human bones. Young's modulus in bending stress was measured in the trabecular section of human *caput femoris*. In twisting stress shear stress modulus and viscous coefficients were determined. Furthermore, content of vitamin D in blood of heads of femur givers was determined and the body mass density (BMD) was measured using dual x-ray denzitometer „Osteoplan+pDXA".

We calculated Young's modulus and shear stress modulus and Poisson's numbers for human materials.

Age-dependent changes of mechanical characteristics of human bones were analyzed. We did not find statistically significant differences, probably due to the limited number of human samples. Another limiting factor was the narrow age range of the donors of these samples.

This dissertation was part of a wider research programme, which focused on determining biomechanical properties of biological materials. A methodology for measurement of mechanical properties of bones was developed and tested within the frame of this work.

Measurement and quantification of mechanical properties of trabecular bone is of importance in many fields of medicine and gerontology. The main limitation of this work is the scarcity of samples and narrow age range of donors. Further research will therefore focus on measuring mechanical properties of bones from younger and healthy donors and on evaluating how age alters the biomechanical properties of bones.